TAB A

COMMENTS ON THE PHYSICAL LAYER ASPECTS OF THE "PETITION FOR RULEMAKING" BEFORE THE FEDERAL COMMUNICATIONS COMMISSION BY PAGEMART INC. DATED FEBRUARY 28, 1992

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EXECUTIVE SUMMARY

The "Petition For Rulemaking" submitted by PageMart Inc dated February 28, 1992 has been reviewed from a technical standpoint. The objective of the review was to determine if the system proposed by PageMart could achieve the technical performance claimed in their submission. Based on the generally accepted rules of cellular system design and RF data communications, the following observations could be made;

- it is quite unlikely that a 4-cell reuse pattern could be used in the cellular system design. Calculations indicate that a 12-cell reuse pattern is required.

- the PageMart system will need far more than twice the number of dedicated receivers as there are base stations. Calculations indicate that for a 0.1 Watt subscriber device, between 25 and 169 dedicated receivers per base station cell site would be required.

- the use of 1 Watt and 10 Watt transmitters for in-building transmission creates a serious problems of co-channel and adjacent channel interference for users outside the building and in adjacent building towers. This is based on the false assumption by PageMart that building walls offers high levels of signal attenuation.

- there is a great deal of concern about the high power base stations presenting unacceptable levels of adjacent-channel interference in the system coverage area. It appears that they could jam themselves as well as subscriber devices near the base sites.

- the requirement on the subscriber device to measure the signal strength of the polling channel for the base sites requires that the subscriber device be powered on for long periods of time. This will drastically reduce the battery life.

- since the PageMart system is not Time Division Duplex, they are susceptible to adjacent channel interference from other units operating within the system on the polling, return link, and data channels. It has been shown that destructive adjacent channel interference extended up to 0.5 miles from each base station site.

- to achieve higher data rates in their system, PageMart will not be able to use low cost subscriber devices. Complexity comparisons with similar speed devices has shown that they will require higher cost DSP, discrete analog/digital or custom VLSI implementations.

- there is considerable doubt that PageMart can achieve 4800 bps data rates on its polling channel, and they would be limited to rates no higher than about 3000 bps.

- the PIMS system proposed by PageMart is very similar to the Ericsson Mobitex system currently operated in Sweden, Norway, Finland, and Canada. This system equipment is also used by RAM Mobile Data Ltd. in their nationwide mobile data network in the United States. Thus it is hardly advanced in nature, nor is it the first system of this type.

1) PageMart claims that a 4-cell reuse pattern is sufficient to "achieve reuse of the spectrum to a much greater extent than is possible with traditional cellular designs" (p. A4).

Using standard cellular system design principles, it is possible to derive the performance characteristics of various frequency reuse strategies. One of the more important parameters is the **co-channel interference (C/I) ratio** provided by the various reuse plans. The co-channel interference ratio can either be used to derive the distance at which the frequency may be reused in a cellular reuse strategy, or to determine if a particular reuse strategy offers sufficient co-channel interference protection against interference from nearest neighbor co-channel transmitters. A standard cellular reuse pattern consists of a 7-cell or larger reuse pattern, where as this 4-cell reuse pattern represents a radical departure from standard practice. Using accepted procedures for cellular system design, it is relatively easy to derive the co-channel interference ratio for this 4-cell reuse pattern.

The basic hexagonal cell structure is shown in figure 1, with the cell radius being defined as d_1. This is consistent with the treatment by Lee [7, p. 52].

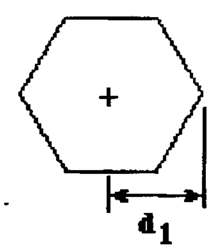

Figure 1 Basic hexagonal cell structure, showing cell radius d_1.

Using this basic cell structure, a four cell reuse plan can be structured as is shown in figure 2. The numbers in the cells indicate the separate frequency assignments, and $d_1 + d_2$ is the reuse distance. The star in the figure represents a portable terminal unit on the edge of cell using frequency 3. The distance to the base station for that cell is d_1, and the distance to the nearest single interfering cell is d_2. From this geometry, it is an easy matter to calculate the co-channel interference from this single co-channel interference source.

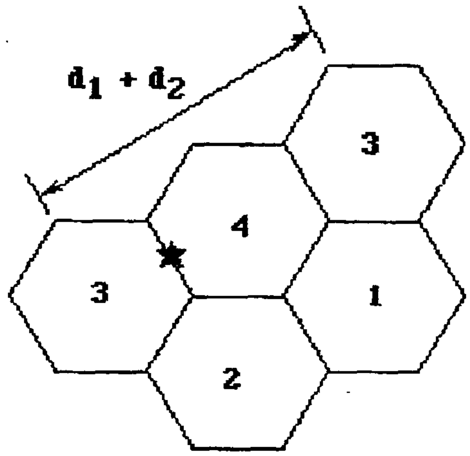

Figure 2 Basic four cell reuse pattern showing reuse distance $d_1 + d_2$. The ★ in figure represents the location of a user on the between the cells using frequencies 3 and 4 of a 4 frequency grouping.

Lee [7, p. 52] shows that the reuse distance for a 4-cell reuse pattern 3.46 times the coverage radius of a single cell and for a standard 7-cell reuse pattern the reuse distance is 4.6 times the coverage radius. Since $d_1 + d_2 = 3.46\ d_F$ for a 4-cell reuse pattern and d_1 is the coverage radius, then $d_2 = 2.46\ d_1$. Let P_1 represent the received power at the user portable device from a base station at a distance d_1 and P_2 represent the power at the user device from a base station at a distance $d_2 = 2.46\ d_1$. Using Lee's Model [3], we can calculate the co-channel interference ratio P_1/P_2 at the user terminal for the 4-cell reuse pattern. In making this calculation, the assumptions made are the following;

- the height of all base station antennas is the same
- the power of the base stations is the same
- the gain of the base station antennas is the same

As a first step, the co-channel interference ratio is calculated for the case of <u>a single co-channel interferer</u>.

$$P_1 = (P_o - 46) - 61.7\ \text{dBm} - 38.4 \log_{10} d_1 + 20 \log_{10}(h1/100) + 10 \log_{10}(h2/10) + G_m$$

$$P_2 = (P_o - 46) - 61.7 \text{ dBm} - 38.4 \log_{10}(d_1 + d_2) + 20 \log_{10}(h1/100) + 10 \log_{10}(h2/10) + G_m$$

Since the path loss parameters are specified in dB (a logarithmic scale), the co-channel interference ratio in dB is the difference of the power levels in dB.

$$\begin{aligned} P_1 - P_2 &= -38.4 \log_{10} d_1 - (-38.4 \log_{10}(d_1 + d_2)) \\ &= -38.4 \log_{10} d_1 + 38.4 \log_{10}(d_1 + d_2) \\ &= 38.4 \log_{10}((d_1 + d_2)/d_1) \\ &= 38.4 \log_{10}((3.46 d_1)/d_1) \\ &= 38.4 \log_{10}(3.46) \\ &= \mathbf{20.7\ dB} \end{aligned}$$

This 20.7 dB figure is for a single interfering channel, and is not truly representative of the cell structure in a largely populated metropolitan user area where the reuse pattern is repeated over a wide geographic area. It is a severe underestimate of the co-channel interference levels that are to be expected in an actual cell structure.

A four frequency reuse pattern where the basic cell pattern is repeated many times is shown in figure 3. It is readily apparent that any cell frequency assignment is surrounded by six nearest neighbor co-channel interferers.

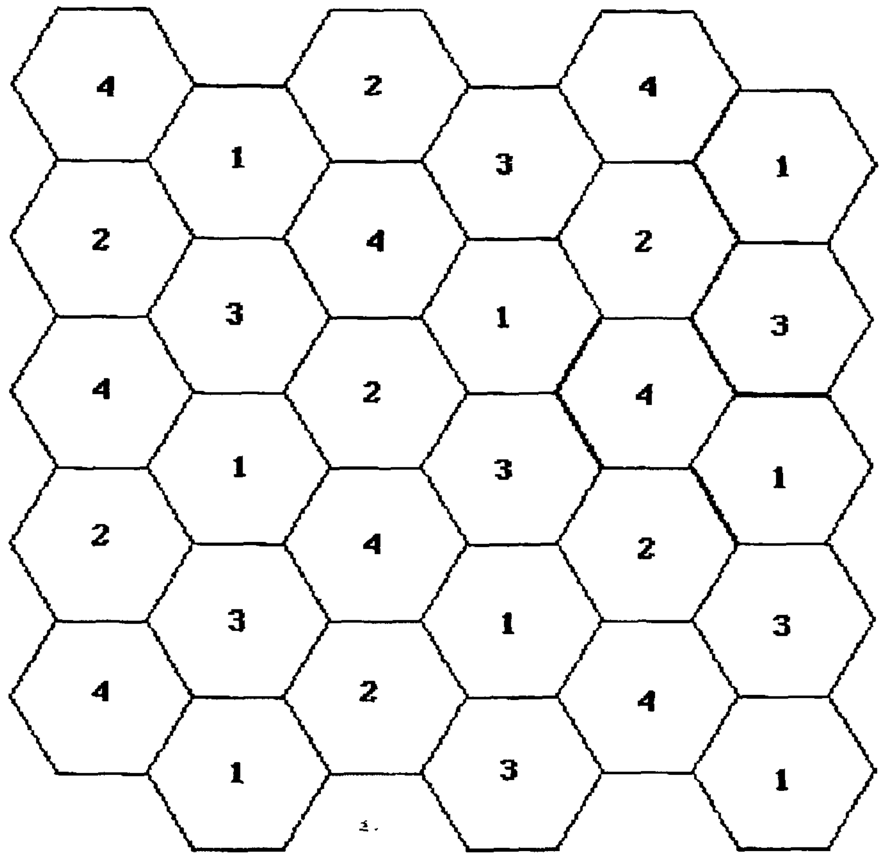

Figure 3 Wide area coverage using repeated 4-cell reuse pattern.

It can be shown using equation 2.4-3 and 2.4-4 of Lee [7, p. 57] that the co-channel interference ratio is given by;

$$C/I = (3K)^{\gamma/2} / 6$$

where

γ = the terrain propagation factor (3.84 in this case)

K = the number of cells in the reuse pattern (4 in this case)

The value of γ is often rounded to be 4.0, but a value of 3.84 shall be used for consistency with coverage distance calculations made throughout this document and with Lee's propagation equations. The parameter K represents the number of cells in the reuse pattern. Therefore a four cell reuse pattern will yield a co-channel interference ratio of

$$C/I = 118.0/6 = 19.67$$

Converting this to deciBels yields a figure of 12.93 dB for the co-channel interference ratio for a 4-cell reuse strategy.

Normal analog cellular design practice is to specify the C/I to be 18 dB or higher, with this figure requiring the classic seven cell reuse pattern. Previous work by the author has found that the 10^{-2} BER capture ratio for binary digital FM in a 25 kHz channel spacing with 4.0 kHz peak deviation and a data rate of 4800 bps was on the order of 22 dB in the fading channel environment. To achieve a C/I protection ratio of 22 dB requires the use of a 12-cell reuse pattern.

The deployment of the PageMart 10-channel nationwide system, with only eight data channels used in a four cell reuse pattern, does not achieve the C/I protection ratios typical of narrowband binary FSK/FM data communication systems. This will result is a degradation in the peak system message rate calculated by PageMart, and hence a **reduction in spectrum efficiency**. The reduction in spectrum efficiency arises from data packets being corrupted by co-channel interference. This corruption will require a retransmission of packets, or could possibly degrade the channel to the extent the the packet retransmission count will be exceeded and the transmission terminated.

If PageMart was able to use the eight data channels in an 8-cell reuse pattern, it would provide only a marginal co-channel interference ratio for the packet data transmission system. However, it should be noted that convenient N-cell reuse "clusters" only occur for specific values of N. The closest value greater than or equal to eight is a 9-cell reuse pattern, thus requiring nine data channels, one polling channel, and one return link channel for a total of 11 channels.

The use of 120 degree sectoring within each cell of a 4-cell reuse pattern is shown by Lee [7, p. 190] to yield a co-channel interference ratio of 14 dB, which again is unacceptable. This would also require 12 data channels instead of 8. If 60 degree sectoring within each cell of a 4-cell reuse pattern is adopted, a 21 dB co-channel interference ratio is obtained. This is a reasonable value for digital RF packet communications. The disadvantages associated with this are that ;

i) more antennas and base station transceivers are required per site, and hence the infrastructure cost increases dramatically.

ii) 24 data channels plus the polling and return link channels are required, for a total of 26 channels <u>representing 650 kHz of total bandwidth for 25 kHz channelization for a single licence holder</u>.

From this analysis, the 4-cell reuse strategy proposed by PageMart does not appear to achieve the spectrum efficiencies claimed. A 12-cell reuse strategy using 12 data channels, one polling channel, and one return link channel appear to be the minimum requirement. The total spectrum required would be a minimum of 350 kHz with 25 kHz channelization.

2) PageMart makes the statement that "the maximum return link power should be limited to 1 Watt or less to ensure minimum interference with other computer communication equipment" (p. 21). They also state that they anticipate "approximately twice as many dedicated receive sites as there are base station locations will be needed" (p. A-5)

Our understanding of this is that the Effective RF Power (ERP) of the portable device is limited to less than 1.0 Watt, which is consistent with the " low powered (0.10 Watt) transceiver that is integrated into a hand-held personal computer product." (p. 8). Yet on p. A13, PageMart proposes "To achieve two-way operation in a high insertion loss building, the unit would be coupled with a separate power module, as depicted in Exhibit XII, which would be capable of generating up to 10 Watts as a transmitter." This is also mentioned on page 9. This is inconsistent with their previous statement of limiting the maximum ERP to 1 Watts, and in fact proposes to use the 10 Watts of power in the very area where they wish to use low power to "ensure minimum interference with other computer and communication equipment".

It is possible to estimate the number of dedicated receiver sites for each base site. Using a 0.1 Watt Effective Radiated Power (ERP), the coverage distance between a portable subscriber device and the base can be calculated. A base station receiver sensitivity threshold of -110 dBm (0.707 microVolts) is assumed. It has also been assumed that the antenna gain at the portable unit is 0 dB, which would be considered extremely good for an external antenna but is exceptional high for an integral internal antenna. The "coverage range" calculation for this case is possible using the generally accepted propagation model of Lee [3].

$$P_r = (P_o - 46) - 61.7 \text{ dBm} - 38.4 \log_{10} d_1 + 20 \log_{10}(h_1/100) + 10 \log_{10}(h_2/10) + G_m$$

where

P_r	=	is the receive sensitivity at the limit of the coverage area (dBm)
P_o	=	transmitter ERP in dBm
d_1	=	is the distance between the receiver and transmitter
h_1	=	antenna height at the cell site (100 feet)
h_2	=	antenna height at the portable unit (10 feet)
G_m	=	antenna gain at the portable unit

Substituting the values in Lee's equation results the following;

$$-110 \text{ dBm} = (20 - 46) - 61.7 - 38.4 \log_{10} d_1 + 20 \log_{10}(100/100) + 10 \log_{10}(10/10) + 0$$

$$38.4 \log_{10} d_1 = 110 - 26 - 61.7 = 22.3$$

Solving for the distance yields;

$$d_1 = 10^{22.3/38.4} = 3.81 \text{ miles}$$

This figure of 3.81 miles **does not** take into account any margins for building penetration loss, log-normal effects, or Rayleigh fading. The margin for Rayleigh is determined by the statistics of the Rayleigh fading envelope. It is typical to choose this margin such that the received signal level is only less than a specific level 5% of the time or less. This is achieved with a Rayleigh fading margin of about 12 dB [4, p.175]. If an 8 dB log-normal margin (typical) is included, then the coverage distance for a portable 0.1 Watt subscriber device on the street is;

$$d_1 = 10^{2.3/38.4} = 1.15 \text{ miles}$$

A large percentage of the subscriber devices will be located within buildings, and will therefore suffer additional path loss due to building attenuation of the RF signal. This attenuation varies widely, depending on building type, height, proximity of windows, etc. Lee [5, p. 279-281] indicates from experiments in the Chicago area that the building penetration loss on the first floor of building is typically 15 dB, although it can be much higher. If we include an additional 15 dB for building penetration loss, then for 0.1 Watt subscriber device in-building we get

$$d_1 = 10^{-12.7/38.4} = \mathbf{0.33 \text{ miles}}$$

This short range coverage distance indicates a fundamental problem with the PageMart system in that a subscriber in a building who is sent an E-mail message or other reasonably large message requiring several transmission blocks (and hence the ARQ transmission strategy described by PageMart in their submission) could send the ACK's or NACK's but they may never be received by the base site if the user is more than 0.33 miles from a receiver site. This problem can be alleviated by placing a large number of remote receivers throughout the coverage area, but a typical metropolitan coverage area of 20 miles x 20 miles would require at least 584 remote receiver sites.

If we assume a typical ERP from a base station, such as 500 Watts ERP (which is well below the maximum 3500 Watts ERP proposed), a receiver sensitivity of -110 dBm, and everything else the same as in the previous derivation, then we get an base station outbound coverage distance of

$$P_1 = (P_o - 46) - 61.7 \text{ dBm} - 38.4 \log_{10} d_1 + 20 \log_{10}(h1/100) + 10 \log_{10}(h2/10) + G_m$$

Rearranging this equation results in;

$$-110 \text{ dBm} = (56.99 - 46) - 61.7 - 38.4 \log_{10} d_1 + 20 \log_{10}(100/100) + 10 \log_{10}(10/10) + 0$$

$$38.4 \log_{10} d_1 = 110 + 10.99 - 61.7 = 59.29$$

and solving for the coverage distance results in;

$$d_1 = 10^{59.29/38.4} = \mathbf{34.99 \ miles}$$

If we include 12 dB Rayleigh fading margin and the 8 dB log-normal distribution loss, the <u>on-street coverage</u> distance is given by;

$$d_1 = 10^{39.29/38.4} = \mathbf{10.54 \ miles}$$

The in-building coverage distance is calculated by including the 15 dB building penetration loss, which yields;

$$d_1 = 10^{24.29/38.4}$$
$$= \mathbf{4.29\ miles}$$

Since only some of the buildings in a metropolitan area will have their own "building-cells", it is necessary to define the coverage area for a base site as being that coverage distance which provides in-building coverage, or the 4.29 miles just derived. Similarly, the portable coverage distance for a portable terminal as being that coverage distance which provides in-building coverage between the portable and the base site, or the 0.33 miles for a 0.1 Watt unit derived earlier.

From these simple calculations, a **ratio of receiver sites to a single base site** can be estimated. It is simply the ratio of the coverage area of the base transmitter to the coverage area of the 0.1 Watt subscriber transmitter. Calculating this ratio yields;

$$N = (2\pi r_1^2)/(2\pi r_2^2)$$
$$= (r_1/r_2)^2$$
$$= (4.29 / 0.33)^2$$
$$\approx \textbf{169 dedicated receive sites per base site !}$$

Using a higher power base station will increase the number of dedicated receive sites per base station site, whereas lowering the base station power will increase the number of base stations to provide over the same geographic area.

This shows that **an excessive number of remote receive sites will be required to provide adequate coverage** between the 0.1 Watt subscriber device and a single base station, which carries with it higher operating costs and hence higher user fees. Since many base sites would be required to provide the required coverage in the MSA's, the total number of remote receive sites would be very large indeed.

Even if PageMart uses a subscriber device of 1.0 Watt instead of 0.1 Watt, the coverage range of the subscriber device is only increased to 0.85 miles. This reduces the number of remote receivers to 25 receivers per base site. Even for a maximum subscriber device power of 1.0 Watt, **the number of remote receivers is well in excess of the "approximately twice as many dedicated receiver sites as there are bases station location" stated by PageMart** (Footnote, p. A-4 and A-5)

3) PageMart proposes an "office cell, which would be configured either as a small wall mount or even desk top unit, is expected to be able to transmit data in the 1 Watt range".

This approach presents the same problem as with the case of propagation from inside the building core to the on-street user considered in the next section. PageMart proposes to provide isolated "office cell coverage" for individual offices within a large building core. This could be done in cases where entire coverage in the building is not installed (such as in older buildings), or one office cell may require enough capacity to justify its own cell. Lee [5, pp. 279 - 283] indicates that an average building penetration loss for the first floor is 15 dB, and it decreases by an average of 2.67 dB per floor. If we consider a 1.0 Watt (30 dBm) office cell and assume that it is located on the first floor of an office building, it will appear to terminals on the street as a 15 dBm (31.6 milliWatt) co-channel or adjacent channel transmitter. If we assume a subscriber device threshold sensitivity of -110 dBm , then the distance from a first floor 1.0 Watt office cell at which an on-street subscriber device can still receive the office cell signal can be calculated using Lee's model. For this calculation, we shall assume a 15 dB building penetration loss [5, pp. 279-281], receiver sensitivity threshold of -110 dBm, subscriber device antenna height of 10 feet, transmitter antenna height of 10 feet, and antenna gains of 0 dB.

$$-110 \text{ dBm} = (P_o - 15 - 46) - 61.7 \text{ dBm} - 38.4 \log_{10} d_1 + 20 \log_{10}(10/100) + 10 \log_{10}(10/10) + 0$$

$$38.4 \log_{10} d_1 = 110 - 31 - 61.7 - 20 + 0 = -2.7$$

$$d_1 = 10^{-2.7/38.4} = \mathbf{0.85 \text{ miles}}$$

Thus, an on-street subscriber device could still receive signals from this office cell at a distance of 0.85 miles. For typical 4800 bps binary FM transmission systems with 4.0 kHz peak deviation, the co-channel interference ratio in a static or non-fading environment is usually at about 9 dB (it is typically about 24 dB in fading environment). Since a desired on-street signal must be 9 dB greater than the interference from the office cell, the effect of this co-channel office cell acting as a co-channel interferer extends even further than the 0.85 miles indicated. It could theoretically extend to a distance of

$$d_1 = 10^{6.3/38.4}$$
$$= 1.45 \text{ miles}$$

In the fading environment this distance is much higher, being about 3.58 miles.

There is some question as to the degree of interference between a building cell and an adjacent building not equipped with a building cell site. In this case, the RF radiation passes through two building walls (at least). The 1.0 Watt office cell transmitter can generate significant co-channel interference in a second office or up to a distance of

$$d_1 = 10^{-8.7/38.4}$$
$$= 0.59 \text{ miles}$$

The discussion so far has dealt only with a unit located on the first or ground floor of a building. As discussed by Lee [7, p. 391], the building attenuation decreases by about 2.7 dB per floor level above the ground floor. For office cell transmitters located above the ground floor of a building, the distance at which that transmitter can still represent a significant co-channel interference source to on-street devices increases. Thus, the interference situation will be much worse than described previously.

Another issue raised by Lee [7, p. 391] is that window areas only provide about 6 dB of attenuation. Any in-building cell or office-cell which has an antenna placed near a window will represent a very strong source of interference to not only on-street receivers, but also to receivers in nearby buildings. This is especially true in the case of newer building construction where there is a considerable amount of glass used on the exterior walls of the building.

Although the concept proposed by PageMart is attractive on the surface, there appear to be some fundamental problems in the areas of propagation and building attenuation which have not been fully addressed. The concept proposed would work well if buildings could be considered as perfect RF enclosures, but the vast majority of buildings cannot be treated as such.

4) **PageMart has claimed that they can provide a "Three-Tiered Cell Architecture". This is accomplished "by creating cells not only in broad geographic areas but also in individual buildings and even individual office suites within buildings". These in-building cells, where the "power per channel would likely be in the 10 Watt range for these facilities", would be "created to service the highly clustered in-building demand in the major high rise office buildings where large groups of subscriber units will be served, mostly during the busy hour period of the normal business day".**

The use of these in-building cells is a good idea to achieve a "micro-cellular" structure in areas of dense user populations. The typically large building penetration losses should provide good isolation between adjacent building towers to provide low co-channel interference levels for **low power levels**, such as in DECT and CT2. However, the use of such powerful transmitters with a four-cell reuse pattern presents a potential for co-channel interference with users **outside** the building. Lee [5, pp. 279 - 283] indicates that an average building penetration loss for the first floor is 15 dB, and it decreases by an average of 2.67 dB per floor. If we consider a 10 Watt in-building cell and assume that it is located on the first floor of an office building, it will appear to terminals on the street as a 25 dBm (316 milliWatt) co-channel or adjacent channel transmitter. The distance from a first floor 10 Watt in-building cell at which an on-street subscriber device can still receive the in-building signal can be calculated using Lee's model. For this calculation, we shall assume a 10 Watt in-building cell, 15 dB building penetration loss (as per Lee), receiver sensitivity threshold of -110 dBm, subscriber device antenna height of 10 feet, transmitter antenna height of 10 feet, and antenna gains of 0 dB.

$$-110\ \text{dBm} = (25 - 46) - 61.7\ \text{dBm} - 38.4 \log_{10} d_1 + 20 \log_{10}(10/100) + 10 \log_{10}(10/10) + 0$$

$$38.4 \log_{10} d_1 = 110 - 21 - 61.7 - 20 + 0 = 7.3$$

$$d_1 = 10^{7.3/38.4} = \mathbf{1.54\ miles}$$

This distance is greater than the on-street coverage distance for a 0.10 Watt subscriber device. The indication from this simple calculation is that there is a **very real potential for destructive co-channel interference to occur between in-building cells and on-**

street cells. This situation can actually be worse in practice, since the windowed areas of buildings have a typical building penetration loss of only about 6 dB [7, p. p.392].

For typical 4800 bps binary FM transmission systems with 4.0 kHz peak deviation, the co-channel interference ratio is usually at about 9 dB for stationary transceivers. Since a desired on-street signal must be 9 dB greater than the interference from the in-building cell, the effect of this co-channel in-building cell acting as a co-channel interferer extends even further than the 1.54 miles indicated. It could theoretically extend to a distance of

$$d_I = 10^{16.3/38.4}$$
$$= \mathbf{2.65\ miles}$$

However, as mentioned before, windowed areas of building have much less attenuation and the co-channel interference could extend much further. We shall assume the typical 6 dB windowed area penetration loss given by Lee [5, pp.279 - 281], then the co-channel interference could extend much further. For a 10 Watt in-building transmitter in the vicinity of a windowed area, the distance at which this transmitter could still present significant co-channel interference to on-street subscriber receivers could be as much as;

$$d_I = 10^{25.3/38.4}$$
$$= \mathbf{4.55\ miles}$$

This is about the same distance as the cell coverage distance considered in previous sections.

Although PageMart assumes that the "percentage of geographic cells that can transmit on a non-interfering basis during building cell transmission cycle = 50%" (p. A-22), it is believed that the figure is far less than this on average and could be as low as 0 % in some cases.

5) PageMart proposes to continually monitor the polling channel to select the best cell site serving the subscriber device.

In the use of such a scanning type of receiver, the receiver synthesizer would have to switched from one channel to the other and then a reading of the signal strength would be required. Because the RF channel exhibits fading, the receiver must stay on each channel long enough to obtain a good statistical average of the mean signal strength for that channel. Lee [6] indicates that between 20 and 40 wavelengths are required to obtain a good statistical average of the average power. For 20 wavelengths, the accuracy would be the order of ±1.56 dB. For a typical walking speed of 4 miles per hour (6.44 kilometers per hour or 1.789 meters per second) at 931 MHz, the wavelength would be the order of 0.31 meters and the 20 wavelengths would represent a distance of 6.2 meters. If the signal strength is measured over only a single wavelength interval, or about 173 milliseconds at a walking speed, the accuracy of the signal strength measurement is about ± 9 dB. To measure the received signal over 20 wavelengths, the receiver must stay on for a period of about 3.5 seconds every time it measures the average power on a channel. This is a considerable amount of time compared to the short batch messages and Go-To messages. This will significantly reduce the battery life, since it increases the receiver on duty cycle.

If we assume that the device listens to the polling channel and that a poll message is the order of 64 bits (2 POCSAG codeword's) at 4800 bps, then the polling time is 0.0133 seconds compared to a channel scan time of 3.5 seconds. To obtain an accurate estimate of the polling channel signal strength, it must be obtained by either averaging over a continuous 3.5 second period, or averaging 263 values of the signal strength measured over each 13.3 millisecond poll messages.

Mtel avoids this problem by having the <u>network</u> select the cell site covered by the receiver which acquired the packet with the best signal quality.

6) PageMart proposes to use one polling channel, one return channel, and eight data channels for the nationwide allocation, and one polling channel, one return channel, and four data channels for the local allocation.

In the use of such a frequency plan, the data channel must be simplex in nature if PageMart is to implement a four cell reuse pattern. The issue of concern here is that these data channels will be very close to the high power base stations, and represent adjacent channel interferers. This problem is alleviated in cellular systems by placing the receive and transmit frequencies apart by 45 MHz, but it cannot be avoided in the AMS service.

A typical high quality telemetry receiver, such as the Motorola OEM RF Transceiver Board has a selectivity of 70 dB and a spurious rejection of 70 dB. Slightly better performance is possible, but at great expense in the subscriber device. The significance of this to the packet data network performance is that the **adjacent** channel signal strength must typically be less than 70 dB above the **desired** channel signal strength in order for the receiver demodulator to correctly receive the message. If we have a 500 Watt ERP base station,

$$(-110 + 70)\ \text{dBm} = (56.99 - 46) - 61.7 - 38.4 \log_{10} d_1 + 20 \log_{10}(100/100) + 10 \log_{10}(10/10) + 0$$

$$38.4 \log_{10} d_1 = 40 + 10.99 - 61.7 = -10.71$$

and solving for the coverage distance results in;

$$d_1 = 10^{-10.71/38.4} = \mathbf{0.526\ miles}$$

Thus, the base station will act as a <u>destructive</u> adjacent channel interferer for a distance of up to 0.526 miles from the base station antenna site, compared with a base station coverage distance of 4.26 miles and a subscriber portable device coverage distance of 1.15 miles.

Another interesting aspect of this problem is that a base site which supports more than one channel, such as one polling channel plus a return link channel and/or one data channel, could present severe adjacent channel interference to itself! It is not clear in the PageMart documentation how they intend to avoid this problem. Mtel avoids this problem by using a Time Division Duplex transmission scheme.

7) PageMart proposes to use higher data rates of 9600 bps and 12000 bps to achieve higher system throughput.

It has been the experience of staff at MPR Teltech Ltd., that data rates above the region 4800 to 6250 bps require the use of Digital Signal Processing (DSP) chips or custom VLSI. These rates are also only achievable through the use of some multi-level signalling scheme, such as 4-level FSK. In fact, modems used on the Mobitex 8000 bps network typically use a DSP chip such as the Texas Instruments TMS320E25. Discrete HC MOS technology modems are possible, but they require about 41 logic devices and are about 28 square inches of board space. This level of complexity is required when multi-level FM systems are used because of the complexity in the demodulator. These complex functions include such things as;

- Receive pulse shaping filters
- Bit timing recovery
- Frequency Offset recovery
- Automatic Gain Control
- Equalization

It is feasible to develop one or more custom VLSI devices which could provide this functionality, as has been considered for implementation of the Mtel modem.

Using present day technology for an 8000 to 9600 bps modem would typically require about 65% of the DSP bandwidth, and hence current consumption during the ON cycle. Typical current consumption by a DSP chip with fast memory is the order of 100 to 200 milliAmps, depending on the actual devices and the clock speeds. Even at 65 % of this, for a range of 65 mA to 130 mA, the current consumption is over one order of magnitude greater than that for a typical one-way paging receiver.

It is doubtful that the very small, low power, and low cost devices claimed by PageMart will achieve these higher data rates.

8) PageMart claims on page A-1 that "PIMS is an advanced messaging service which permits users instantaneously to receive or send text and graphic of any length, in any format... PIMS achieves spectrum efficiencies, cost savings and network capacities which are orders of magnitude superior to existing of proposed services or technologies" They also claim that "PIMS is the first truly personal, portable and ubiquitous two-way information messaging service. Such information messaging is currently unavailable or uneconomic using existing paging, cellular or other packet network technologies". (p. 1).

In the petition for rulemaking application, PageMart indicates that PIMS is a technologically advanced two-way messaging service. This is achieved through;

- "dramatic advances in spectrum efficiency and architectural flexibility"
- "advanced combinations of radiolocation, frequency reuse ..."
- "No existing or proposed communications technology can, in a "stand-by" mode, instantaneously and automatically deliver similar amounts of information at comparable costs and with comparably efficient utilization of spectrum"

The system described by PageMart is remarkably similar to the Mobitex packet radio network which is operated by **RAM MOBILE DATA INC.** The RAM network provides customers with applications such as messaging, remote data base access, and remote data collection. Users gain access to the network via a local base station or leased line to a local switching node. Datagram packets up to 512 bytes in length and coded as ASCII text or transparent data are the basis for all communications. Higher level protocols, such as transport and presentation levels, may be overlaid by the user. Other key network features are;

- trunked frequency reuse design and channelization in which no fewer than 10 and as many as 30 radio frequency pairs are available.
- intelligent base stations and automatic registration. Messages are switched between terminals within a coverage area of a particular base station where possible to reduce network overhead. Information concerning the location of each terminal is relayed to higher network nodes, so that their movements can be tracked as they roam throughout the local area, region, or the nation. This "roaming capability is achieved by using the received signal strength as a radio location mechanism.
- high data rate over the air, with 8000 bps being the raw channel data rate.
- Non-proprietary over the air protocol.
- store and forward mailbox capability.
- incorporation of a battery saving mode in the subscriber device to extend the battery life or operating time on a single charge cycle.

- supports the concept of active (powered on) and inactive (powered off), allowing messages that have been stored in the subscribers network mailbox to be sent to the terminal when communication is re-established. This is useful in cases where the RF communication path is disrupted due to disruption of the RF path (high building penetration losses), the requirement that the user turn the device off (ie., near blasting sites), etc.

Future enhancements proposed by RAM include an application level gateway such as X.400 to allow electronic mail exchange with other networks.

The system operation is very similar to that proposed by PageMart. RAM uses a single full duplex "System Channel" (which serves the functions of the polling and return channel in the PageMart system) to direct subscriber devices to one of the remaining 9 channel pairs. This is a typical trunking mode of operation.

The Mobitex system specification are dated in the 1988 and 1989 time frame, with recent changes being made to the system specification to support roaming and other features. The claim by PageMart that PIMS is **"a technologically advanced two-way messaging service"**, in light of the high degree of similarity between PIMS and Mobitex, is simply not true.